Supplemental Information: Uncovering Gunshot Residue Flow and Deposition Mechanisms using Novel Visualization Methods, Real-time Atmospheric Particle Sampling, and Spectrochemical Techniques

This document details images, provides access and additional details to videos referenced within the main text of the article, and provides additional details on a study subsection investigating the analysis of particles that had been captured by the custom-made particle counters. All supplemental videos follow a similar premise, in which some form of gunshot residue (GSR) released by a firearm is illuminated by a laser sheet. Videos range from 10 s to several min to capture the flow and effects that the environments and conditions have on the resulting GSR. When possible, a short duration of laser exposure to the atmosphere (before a firing event) has been included in the videos to demonstrate the clear difference between common atmospheric particulates (*i.e.*, dust) and GSR. Supplemental videos may be viewed in-document by clicking on the triangular "play" button or by following the link provided to view in full screen and high definition (recommended).

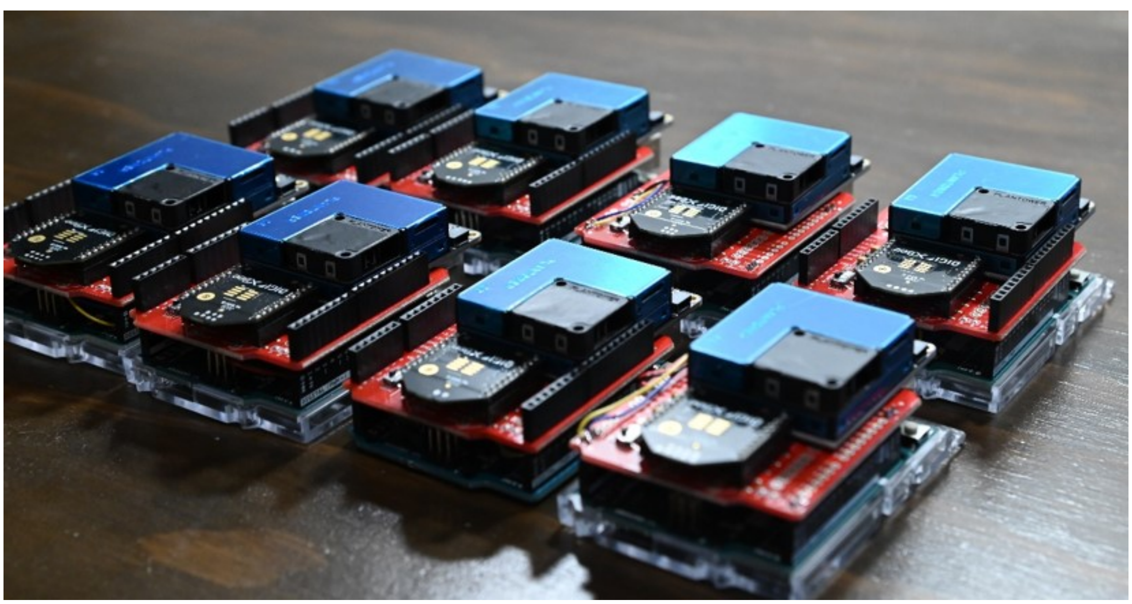
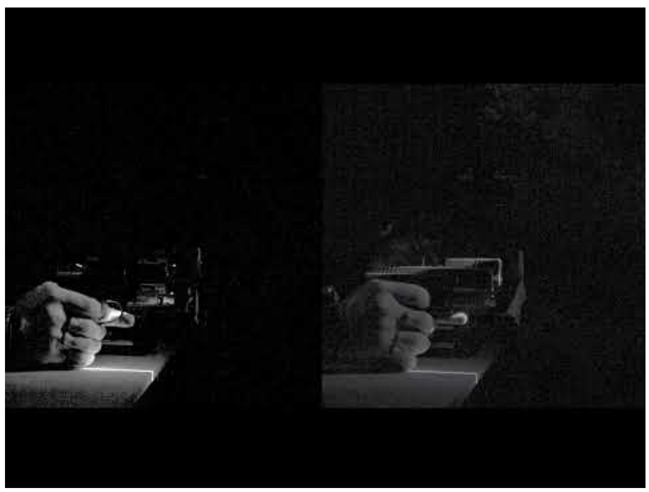


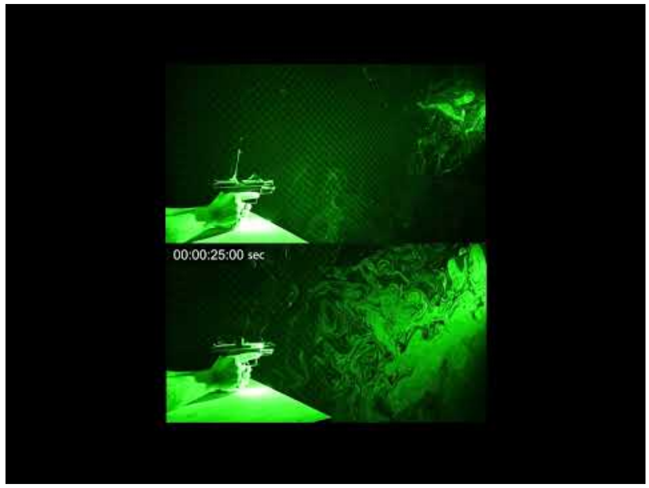
Figure S1: *An image of the custom-made particle counters used in this study for simultaneous airborne sampling of GSR in various locations.*

Table S1. *Figures of merit for the LC-MS/MS method used in this study. The method includes the targeted analysis of six compounds: diphenylamine (DPA), methyl centralite (MC), ethyl centralite (EC), 2-nitrodiphenylamine (2-NDPA), akardite II (AKII), and 4-nitrodiphenylamine (4-NDPA). Limits of detection and quantitation are listed in µg/L.*

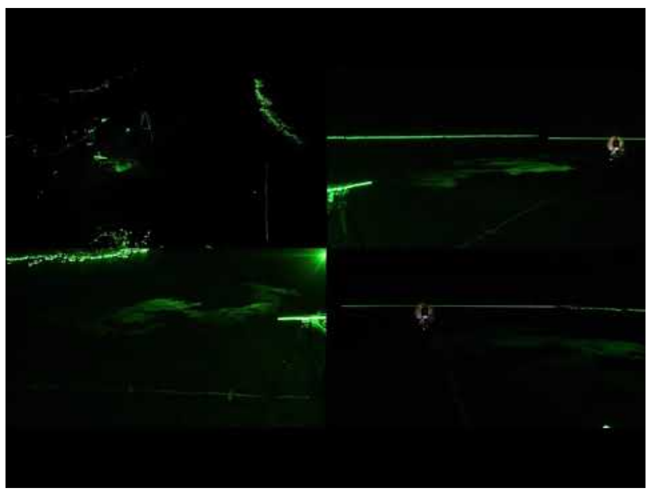
Compound	LOD (µg/L)	LOQ (µg/L)	% RSD Intra-day	% RSD Inter-day	LDR (µg/L)	R^2
DPA	3.4	10	3.7	10	10-200	0.999
MC	0.3	0.9	2.7	11	1-200	0.999
EC	1.0	3.0	1.1	9.3	5-200	0.999
2-NDPA	2.7	8.2	4.6	4.0	10-200	0.997
AKII	0.3	0.9	1.3	4.8	1-200	0.999
4-NDPA	3.0	9.0	7.9	6.4	10-200	0.999



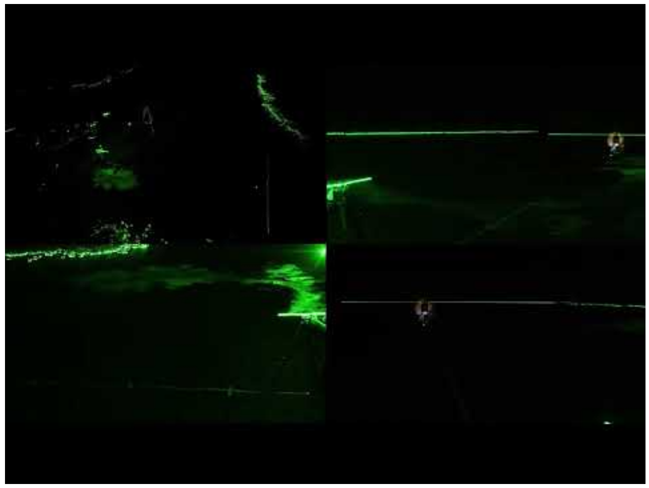
Video S1: *This video demonstrates the use of laser sheet scattering coupled with high-speed videography. In this video, two trials have been synchronized, showing the firing of one shot of Winchester Target & Practice 9 mm ammunition by the Taurus Model 905 (left) and the Springfield XD-9 (right). Experiments shown in this video were performed in an indoor environment.*



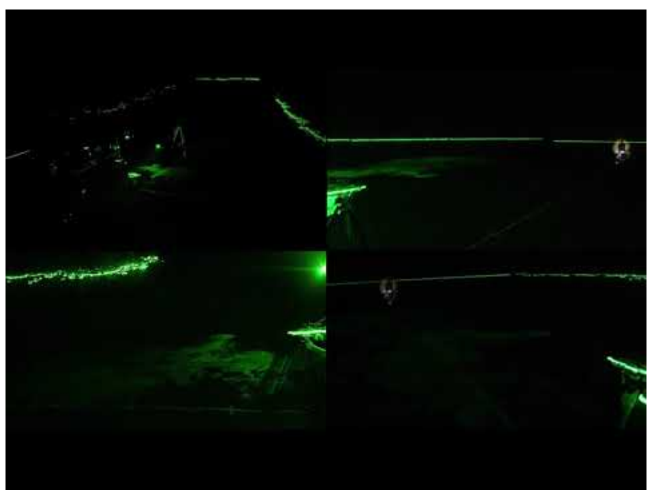
Video S2: *This video demonstrates the use of vertical laser sheet scattering to show a comparison of a single shot (top) and five shots (bottom) of Winchester Target & Practice 9 mm ammunition by the Springfield XD-9. Experiments shown in this video were performed at the indoor range.*



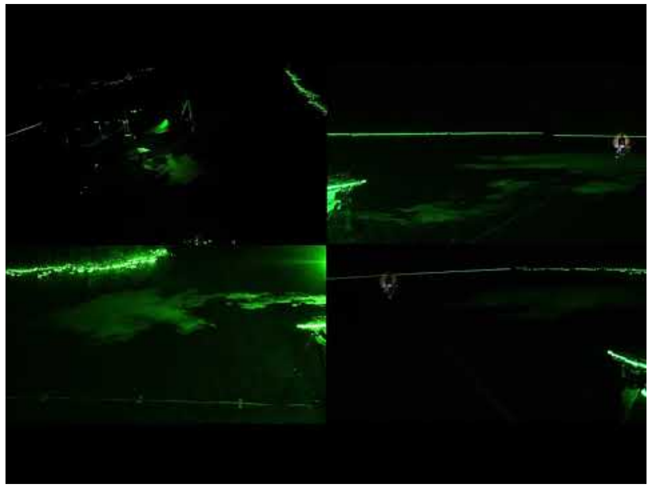
Video S3: *This video demonstrates the use of horizontal laser sheet scattering to show the flow dynamics of a DPMS AR-15 firing a* ***single shot*** *of Winchester M855 5.56x45 mm NATO ammunition. The experiment in this video was performed at the outdoor range. Four camera angles from the same trial have been synchronized. (top-left: drone footage, top-right: right facing forward, bottom-left: left facing orthogonal to the path of bullet, bottom-right: left facing forward).*



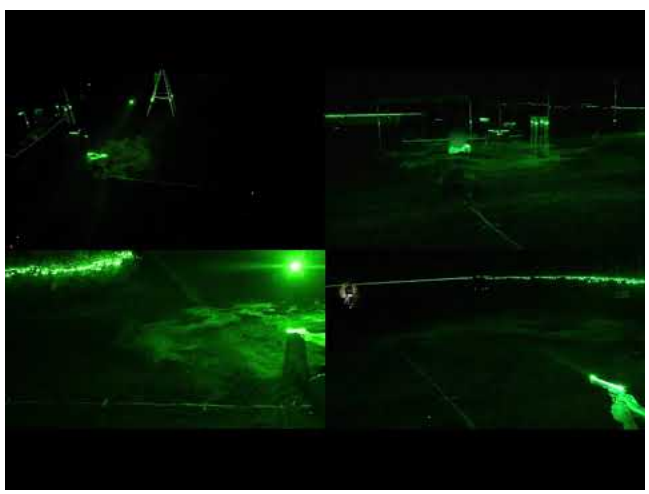
Video S4: *This video demonstrates the use of horizontal laser sheet scattering to show the flow dynamics of a DPMS AR-15 firing* ***five shots*** *of Winchester M855 5.56x45 mm NATO ammunition. The experiment in this video was performed at the outdoor range. Four camera angles from the same trial have been synchronized (top-left: drone footage, top-right: right facing forward, bottom-left: left facing orthogonal to the path of bullet, bottom-right: left facing forward).*



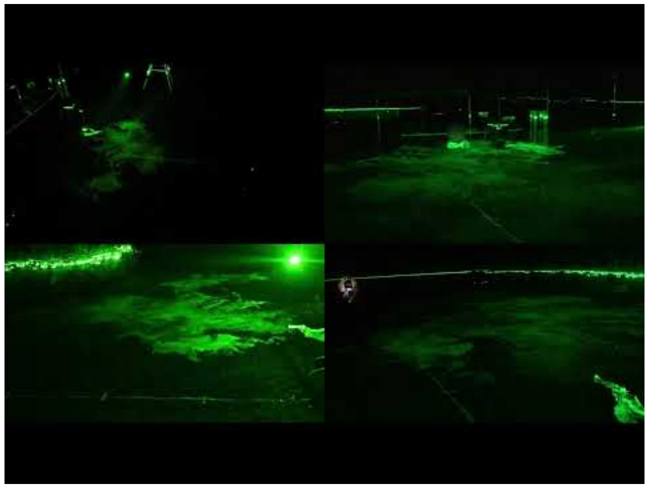
Video S5: *This video demonstrates the use of horizontal laser sheet scattering to show the flow dynamics of a Kel-Tec RDB firing* ***a single shot*** *of Winchester M855 5.56x45 mm NATO ammunition. The experiment in this video was performed at the outdoor range. Four camera angles from the same trial have been synchronized (top-left: drone footage, top-right: right facing forward, bottom-left: left facing orthogonal to path of the bullet, bottom-right: left facing forward).*



Video S6: *This video demonstrates the use of horizontal laser sheet scattering to show the flow dynamics of a Kel-Tec RDB firing* ***five shots*** *of Winchester M855 5.56x45 mm NATO ammunition. The experiment in this video was performed at the outdoor range. Four camera angles from the same trial have been synchronized (top-left: drone footage, top-right: right facing forward, bottom-left: left facing orthogonal to path of the bullet, bottom-right: left facing forward).*

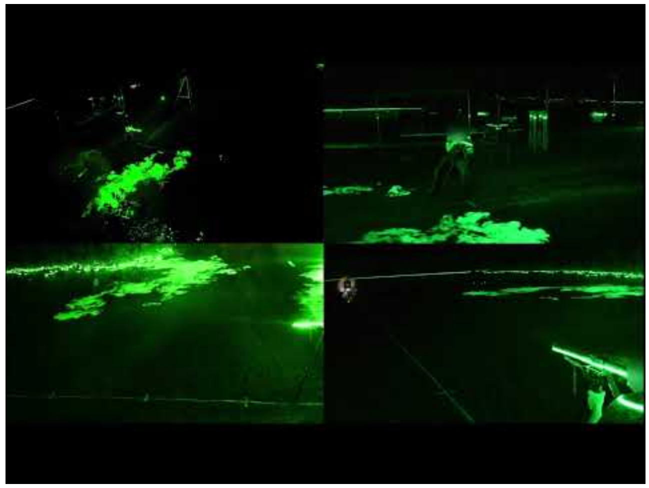


Video S7: *This video demonstrates the use of horizontal laser sheet scattering to show the flow dynamics of a Smith and Wesson Model 686-6 firing* ***a single shot*** *of Winchester .357 magnum ammunition. The experiment in this video was performed at the outdoor range. Four camera angles from the same trial have been synchronized (top-left: drone footage, top-right: right facing the shooter, bottom-left: left facing orthogonal to path of bullet, bottom-right: left facing forward).*

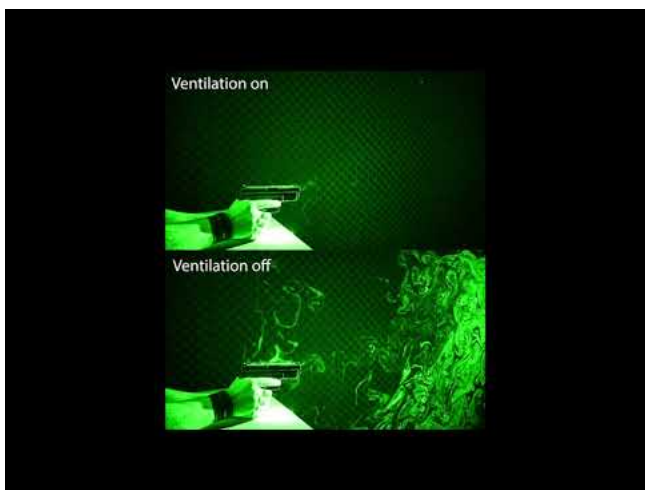


Video S8: *This video demonstrates the use of horizontal laser sheet scattering to show the flow dynamics of a Smith and Wesson model 686-6 firing* ***five shots*** *of Winchester .357 magnum ammunition. The experiment in this video was performed at the outdoor range. Four camera angles from the same trial have been synchronized (top-left: drone footage, top-right: right facing the shooter, bottom-left: left facing orthogonal to path of bullet, bottom-right: left facing forward).*

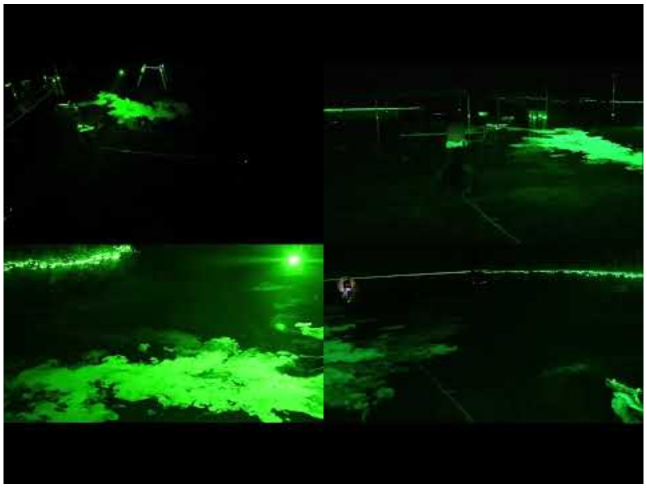
Video S9: *This video demonstrates the use of horizontal laser sheet scattering to show the flow dynamics of a Winchester Defender firing* ***one shot*** *of Remington 12 ga. Magnum buckshot ammunition. The experiment in this video was performed at the outdoor range. Four camera angles from the same trial have been synchronized (top-left: drone footage, top-right: right facing the shooter, bottom-left: left facing orthogonal to path of bullet, bottom-right: left facing forward).*



Video S10: *This video demonstrates the use of horizontal laser sheet scattering to show the flow dynamics of a Traditions Deerhunter firing **one shot** of .50 caliber ball ammunition loaded with a 70-grain charge of Pyrodex RS. The experiment in this video was performed at the outdoor range. Four camera angles from the same trial have been synchronized (top-left: drone footage, top-right: right facing the shooter, bottom-left: left facing orthogonal to path of bullet, bottom-right: left facing forward)*.

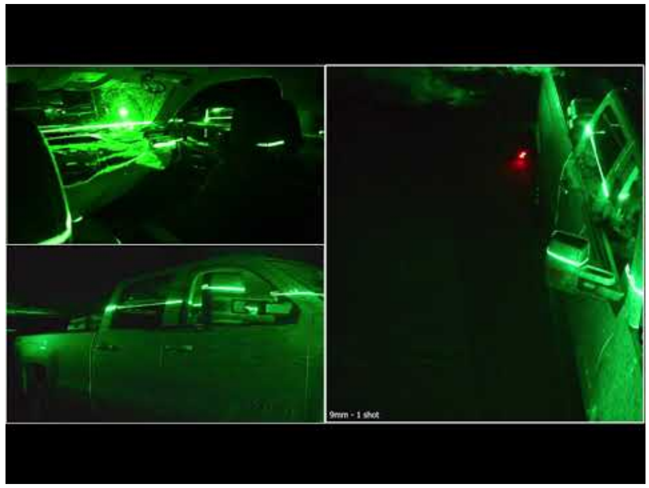


Video S11: *This video demonstrates the use of vertical laser sheet scattering to show a comparison of a **single shot** of Winchester Target & Practice 9 mm ammunition by the Springfield XD9 with the range ventilation on and off. Experiments shown in this video were performed at the indoor range.*



Video S12: *This video demonstrates the use of horizontal laser sheet scattering to show the flow dynamics of a Springfield XD9 firing* ***five shots*** *of Winchester Target & Practice 9 mm ammunition. The experiment in this video was performed at the outdoor range. Four camera angles from the same trial have been synchronized (top-left: drone footage, top-right: right facing the shooter, bottom-left: left facing orthogonal to path of bullet, bottom-right: left facing forward).*

Video S13: *This video demonstrates the use of vertical laser sheet scattering to show the firing of five shots of Winchester Target & Practice 9 mm ammunition by the Springfield XD9. Experiments shown in this video were performed at the indoor range.*



Video S14: *This video demonstrates the use of horizontal laser sheet scattering to show the firing of one shot of Winchester Target & Practice 9 mm ammunition by the Springfield XD9 from a 2022 Chevrolet Silverado. Experiments shown in this video were performed at the outdoor range. The shooter is positioned in the driver's seat and is firing out the passenger window (open).*

Video S15: *This video demonstrates the use of horizontal laser sheet scattering to show the firing of one shot of Winchester Target & Practice 9 mm ammunition by the Springfield XD9 from a 2016 Volkswagen Jetta. Experiments shown in this video were performed at the outdoor range. The shooter is positioned in the driver's seat and is firing out the passenger window (open).*

Video S16: *This video demonstrates the use of horizontal laser sheet scattering to show the firing of one shot of Winchester Target & Practice 9 mm ammunition by the Springfield XD9. In this scenario, the shooter and bystander are positioned in a similar manner to which other experiments in this study were performed to visually demonstrate the possibility of a bystander's exposure to GSR. Experiments shown in this video were performed at the indoor range.*

Chemical and Elemental Analysis of Sensor-counted Particles

The setups shown in **Figures 3** and **4** were used with collection devices held by the persons of interest. For indoor experiments, carbon adhesive stubs were affixed two mm away from the exhaust of the custom-made particle counters. The purpose of this is to collect particles that have passed through the sensor, including IGSR, OGSR, and any environmental particles that may be present. Ten s before firing by the shooter, data collection with the APS and particle counters began. After five min, the door to the range was slowly opened to allow light, passive airflow to simulate a scenario in which a passerby opens a door to enter a room. After an additional five min, the passerby entered the room and remained stationary behind the bystander for five min (15 min total). To prepare for the next sample the air purification system in the range was turned on to remove airborne GSR. A total of five trials were performed in this experiment.

Chemical and Elemental Analysis of Sensor-Counted Particles

The GSR analysis by SEM-EDS and LC-MS/MS evaluated the elemental and chemical makeup of counted particles. These methods provided additional confidence that the particles counted were indeed GSR and provided further understanding of the behaviors of the inorganic and organic residues. The sampling at the exhaust of the counters was also investigated as a potential preconcentration device in enclosed rooms.

LC-MS/MS and SEM-EDS Analysis of Preconcentrated Stubs

LC-MS/MS analysis of preconcentrated stubs (*n=15*) showed results below the detection limit (<LOD, **Table S1**) for all six compounds, suggesting two possibilities. First, it is possible that the majority of particles observed by the particle counters are *not* organic in nature. Second, it is possible that while some may be organic in nature, they occur in an overall mass that is too low for our extraction and instrumental method to measure. While the reality lies unknown and would require further testing, this is evidence that, unlike the inorganic residues, the organic residues may not transfer from the firearm to the atmosphere *and* remain suspended long enough for the particle counters to measure them.

The analysis of preconcentrated stubs for inorganics (*n=15*) was greatly different from LC-MS/MS. SEM-EDS analysis showed an average of 105 particles characteristic (containing Pb, Ba, and Sb) and 128 particles consistent with GSR (containing only two of Pb, Ba, or Sb). Regardless of sensor position, IGSR was found on each preconcentrated stub. This finding is integral to the use of particle counters and the APS to evaluate the flow and deposition of GSR, as it provides the necessary confirmation that particles passing through the respective sensors are GSR. Additionally, the confirmation of elemental profiles of preconcentrated particles provides evidence that inorganic particles may be more prone to inadvertent deposition on surfaces following a firing event. These findings open an opportunity to use the particle counters as a pre-concentration device in enclosed environments suspected of recent shootings (<three h after the discharge of a firearm).